

[54] **ELECTRON EMISSIVE DEVICE
INCORPORATING A SECONDARY
ELECTRON EMITTING MATERIAL OF
ANTIMONY ACTIVATED WITH
POTASSIUM AND CESIUM**

117/217, 219, 215

[75] Inventor: **Alfred Hermann Sommer**, Princeton,
N.J.

[73] Assignee: **RCA Corporation**, New York, N.Y.

[22] Filed: **Dec. 3, 1971**

[21] Appl. No.: **204,697**

Related U.S. Application Data

[63] Continuation of Ser. No. 34,699, May 5, 1970,
abandoned.

[52] U.S. Cl. **313/103**, 117/217, 117/219,
313/94

[51] Int. Cl. **H01J 43/00**

[58] Field of Search 313/94, 103, 104;

[56]

References Cited

UNITED STATES PATENTS

2,770,561	11/1956	Sommer	117/219 X
2,881,343	4/1959	Polkosky et al.	313/103 X
3,023,131	2/1962	Cassman	117/219 X
2,914,690	11/1959	Sommer	117/217 X
2,574,356	11/1951	Sommer	117/217 X

Primary Examiner—Rudolph V. Rolinec

Assistant Examiner—Saxfield Chatmon, Jr.

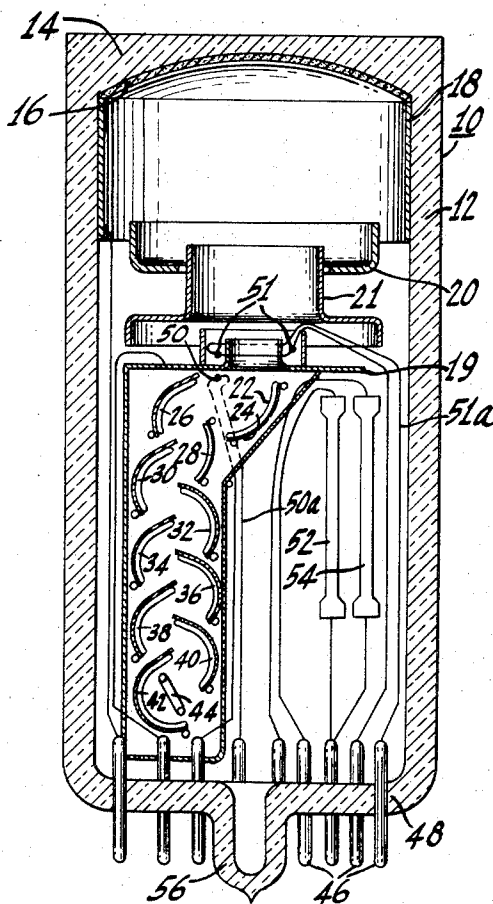
Attorney—Glenn H. Bruestle and Donald S. Cohen

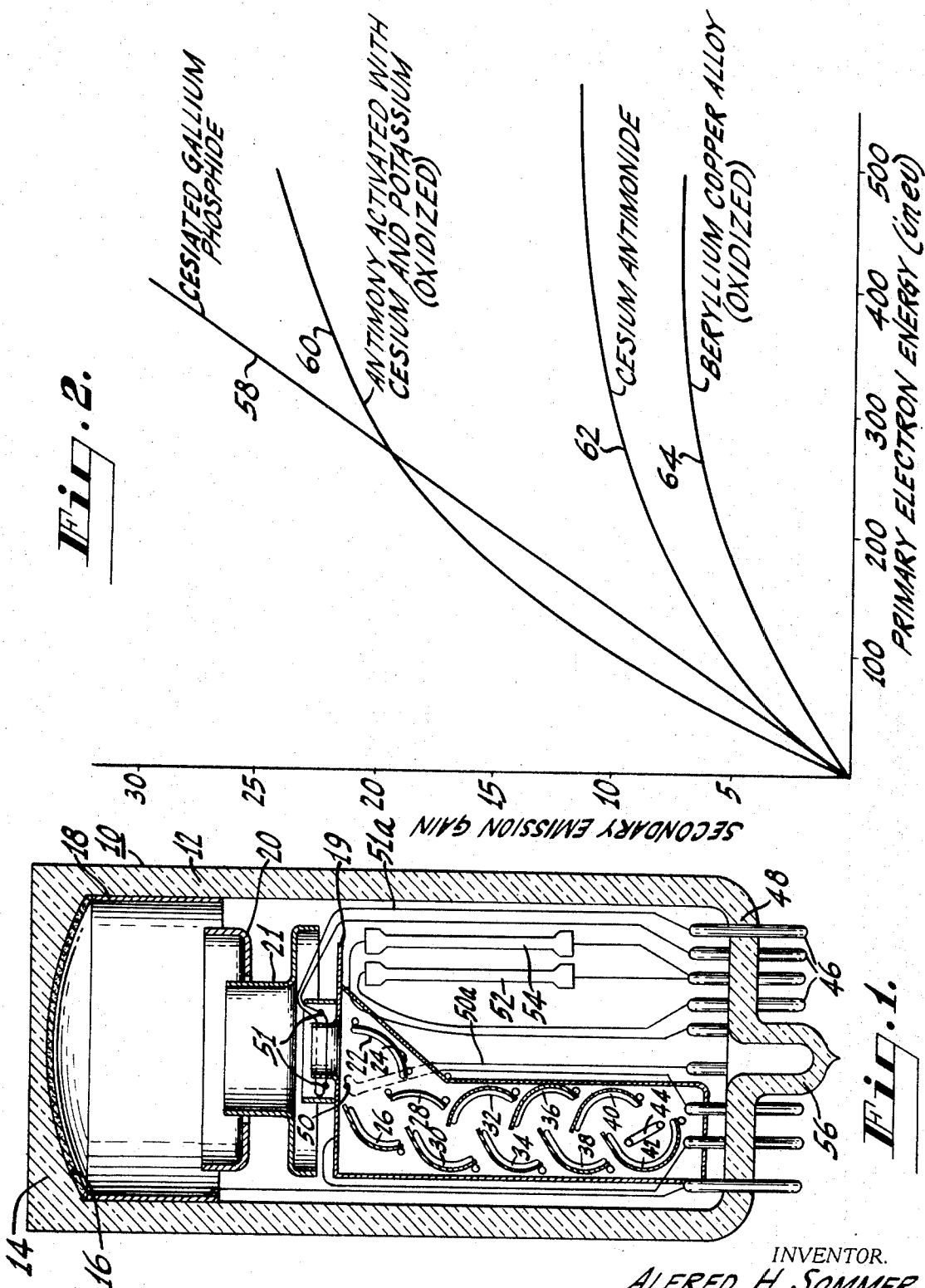
[57]

ABSTRACT

In an electron emissive device having electron multiplying dynodes, the dynode surfaces upon which the electrons impinge are provided with a layer of anti-mony activated with cesium and potassium.

5 Claims, 2 Drawing Figures





INVENTOR.
ALFRED H. SOMMER
 BY
Volker R. Ulbrich
 Attorney

ELECTRON EMISSIVE DEVICE INCORPORATING A SECONDARY ELECTRON EMITTING MATERIAL OF ANTIMONY ACTIVATED WITH POTASSIUM AND CESIUM

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of applicant's co-pending application Ser. No. 34,699 filed May 5, 1970, now abandoned.

BACKGROUND OF THE INVENTION

The invention relates to electron emissive devices utilizing secondary electron emitting surfaces.

Photomultiplier tubes, such as for instance those described in U.S. Pat. No. 3,099,764 to A. F. McDonie et al., commonly have a photocathode surface and at least one electron multiplying dynode having a secondary electron emitting dynode surface. Electrons emitted from the photocathode in response to light are focussed by electrodes to the secondary electron emitting surface of a first dynode. Upon impinging on the first dynode surface, the electrons are multiplied, and may be further multiplied at additional dynodes, until they are collected by an anode to result in a signal current.

Photomultiplier tubes used for scintillation counting generally have a photocathode with a potassium-cesium-antimony composition. For a particular structural design of the tube, the tube performance is largely dependent on the secondary emission gain of the dynodes. The secondary emission of the first dynode is especially critical for improving the signal-to-noise ratio of the tube. Typical materials used for secondary electron emitting dynode surfaces are, for instance, oxidized silver-magnesium, oxidized beryllium copper alloy, cesium antimonide Cs_3Sb , and cesiated gallium phosphide $\text{GaP}(\text{Cs})$. Whereas the secondary emission performances of the first three materials are comparable to one another, the performance of $\text{GaP}(\text{Cs})$ is greatly superior. However, since $\text{GaP}(\text{Cs})$ required considerable special processing, its use in a photomultiplier tube results in substantially increased cost.

SUMMARY OF THE INVENTION

The invention is a novel and improved electron emissive device of the type having means for emitting electrons into an evacuated space and a secondary electron emitting material in the evacuated space. The electrons impinge on the material and are multiplied by secondary emission. The improvement comprises that the secondary electron emitting material consists essentially of antimony activated with potassium and cesium.

While the performance of the novel device is comparable to that of a similar device with a cesiated gallium phosphide layer on its dynode, the novel device requires a minimum of special processing and is therefore substantially less costly to fabricate.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view of a phototube having a first dynode provided with a secondary emissive layer according to a preferred embodiment of the invention.

FIG. 2 is a graph showing the general relative secondary emission properties of various secondary electron emitting materials, including the emitting material of the dynode of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In a first preferred embodiment of the invention, a first dynode of a phototube is provided with a secondary electron emitting layer consisting essentially of a layer of antimony activated with potassium and cesium. Referring now to FIG. 1, the phototube 10 has an envelope about 5 inches long and 2 inches outside diameter comprising a cylindrical glass wall 12 and a glass faceplate 14. On the inside surface of the faceplate 14 is a photocathode consisting essentially of a layer of antimony activated with potassium and cesium. Near the photocathode 16 and on the inside wall surface is a vapor deposited aluminum focussing electrode 18. Situated in the interior space of the tube 10 and spaced from the wall 12 are additional focussing electrodes 19, 20, 21. The emitted electrons, guided by appropriate electrostatic fields provided by the focussing electrodes 19, 20, 21, impinge upon a secondary electron emitting layer 22 on a first dynode 24. The dynode is of thin nickel metal. The layer 22 is a potassium-cesium-antimony composition consisting essentially of a layer of antimony activated with potassium and cesium and is believed to have approximately the composition represented by the chemical formula K_2CsSb . The layer 22 has generally the same composition as the photocathode 16. At the first dynode 24, the electrons are multiplied by secondary emission from the layer 22. The multiplied electrons pass to the second dynode 26 and to succeeding dynodes 28, 30, 32, 34, 36, 38, 40, 42, where they are again multiplied in a similar manner until they are finally collected by an anode 44. Appropriate voltages are applied to the dynodes and a signal transmission line is connected to the anode 44 through leads 46 in a stem 48 closing the bottom of the tube wall 12.

An antimony bead 50 for evaporating antimony on the first dynode 24, and two beads 51 situated in an annular space in electrode 19 for evaporating antimony on the inside surface of the faceplate 14, are bonded to resistance heating wires 50a and 51a respectively. Resistance heated channels 52, 54 are positioned inside the tube 10 for providing cesium and potassium vapors. The cesium channel 52 contains a mixture of cesium chromate, zirconium, and tungsten. The potassium channel 54 contains a mixture of potassium chromate, aluminum, and tungsten.

The fabrication of the tube 10 is generally as follows: The component parts of the tube 10 are assembled and the tube 10 is evacuated through exhaust tubulation 56 (shown tipped off) in the stem 48 to a pressure of about 10^{-8} torr. The antimony beads 50, 51 are evaporated to form a thin antimony layer on the inside surface of the faceplate 14 until the light transmission through the faceplate 14 is decreased to about 80 percent of its initial transmission, and on the surface of the first dynode 24. While the thickness of the antimony layer on the first dynode 24 is not critical, it is desirable that the thickness be at least equal to that of the antimony layer on the faceplate 14. First potassium, and then cesium, are alternately vaporized from the channels 52, 54 to a maximum photoelectric sensitivity of the tube in accordance with known techniques for activating antimony to form a photocathode. The tube temperature is held at 170°C during the activation. Methods for activating antimony with alkali metals are described in

detail, for instance, in U.S. Pat. No. 2,770,561 to A. H. Sommer. The result is a simultaneous formation of the photocathode 16 and the layer 22 on the first dynode 24. Superficial oxidation of the layer 22 further increases the degree of secondary emission of the layer 22 on the first dynode 24. Superficial oxidation may be provided by introducing a small quantity of oxygen into the tube 10 at room temperature after the activation of the antimony with K and Cs until a maximum tube sensitivity is reached. Then the tube 10 is tipped off under vacuum.

In a second embodiment, all the dynodes 24-42 of the tube 10 in FIG. 1 are coated with a layer consisting essentially of antimony activated with potassium and cesium. A separate antimony source, such as for instance a radio frequency heated antimony coated metal tape, may be mounted near each of the dynodes 24 to 42 for evaporating an antimony layer on the dynodes 24 to 42. Then, the antimony is activated with potassium and cesium generally as in the first embodiment.

In a third embodiment of the invention, the dynodes 24 to 42 in the tube 10 of FIG. 1 are provided with an antimony coating before the tube 10 is assembled. Then, the antimony is activated with potassium and cesium in the tube 10 as in the first embodiment. By providing the antimony coating on the dynodes 24 to 42 prior to tube assembly, the necessity of mounting one or more antimony beads in the tube 10 for evaporating antimony on the dynodes 24 to 42 is eliminated.

In a fourth embodiment, antimony coatings of one or more of the dynodes 24 to 42 of the tube 10 in FIG. 1 are activated with potassium and cesium, generally as in the first embodiment, and superficially oxidized. Thereafter, antimony is evaporated on the inside surface of the faceplate 14. The antimony on the surface of the faceplate 14 is then activated with K and Cs generally as in the first embodiment. There is no superficial oxidation of the photocathode 16. The additional exposure to potassium and cesium of the already-activated antimony on the dynodes 24 to 42 is not detrimental. Also, the exposure of the inside surface of the faceplate 16 to potassium and cesium during activation of the antimony on the dynodes 24 to 42 is not detrimental. In this embodiment, the secondary electron emitting layer on the dynodes 24-42 is superficially oxidized, while the photocathode 16 is not superficially oxidized. This condition is desirable since, for antimony activated with potassium and cesium, superficial oxidation increases the secondary emission gain but may be detrimental to the photoelectric performance because of increased dark emission.

General Considerations — A secondary electron emitting layer consisting essentially of a layer of antimony activated with potassium and cesium may be used in any electron discharge device wherein electrons are emitted into a vacuum and impinge on the secondary electron emitting layer for multiplication. Such devices include, for example, phototubes, television camera tubes, and storage tubes. It is especially advantageous for use in devices which include also another layer, such as a photocathode, which is activated

with potassium and cesium, since the same source of K and Cs may then be used to activate both the photocathode and the secondary electron emitting layer. In some instances, such as where the photocathode of a phototube is also a layer consisting essentially of antimony activated with potassium and cesium, both the photocathode and the secondary electron emitting layer may be formed by only a single activation process, as in the first embodiment. Where a phototube has a multi-alkali photocathode containing potassium, cesium, sodium, and antimony, the sources of potassium and cesium may be used for forming a secondary electron emitting layer on dynodes prior to their use in the formation of the photocathode. Thus, the layer on the dynodes may be formed without the inclusion in the device of additional processing materials. The choice of substrate material for supporting the layer is generally not critical.

FIG. 2 shows the comparative secondary emission gains of a layer consisting essentially of antimony activated with potassium and cesium and superficially oxidized, and three other secondarily-emissive materials mentioned above with respect to the background of the invention. The curves 58, 60, 62, and 64 shown are for GaP(Cs), antimony activated with cesium and potassium and superficially oxidized, Cs₃Sb, and oxidized beryllium-copper alloy, respectively. The gain of antimony activated with potassium and cesium but not superficially oxidized lies approximately midway between the curves 60 for the superficially oxidized material and 62 for cesium antimonide. It is seen that for primary electron energies of up to 300 ev, the range of energies generally used for photomultiplier tubes, the secondary emission gain of the oxidized material shown by the curve 60 is comparable to that of the cesiated gallium phosphide shown by curve 58. Yet, the antimony activated with potassium and cesium is considerably less difficult to form in a tube.

I claim:

1. An electron emissive device of the type having means for emitting electrons into an evacuated space and a secondary-electron-emitting material in said evacuated space, said electrons impinging on said material and being multiplied by secondary emission, said secondary-electron-emitting material consisting essentially of a compound of antimony, potassium, and cesium, and has approximately the chemical composition represented by the chemical formula K₂CsSb.

2. The device defined in claim 1 and wherein said secondary-electron-emitting material is superficially oxidized.

3. The device defined in claim 1 and wherein said means for emitting electrons is a photocathode.

4. The device defined in claim 3 and wherein said photocathode comprises at least one alkali metal chosen from the group consisting of potassium and cesium.

5. The device defined in claim 4 wherein said photocathode and said secondary-electron-emitting material have substantially the same chemical composition.

* * * * *